CINDERFORD NORTHERN QUARTER BAT MONITORING STRATEGY

Report for Forest of Dean District Council

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1 INTRODUCTION

1.1 Background

1.1.1 The Northern Quarter is located to the north of the market town of Cinderford, on the western edge of the Forest of Dean in Gloucestershire. It extends to approximately 84 ha, part of which has been subject to extensive mining and clay extraction activities in the past. The area now consists of woodland, grassland, wetlands and disused industrial areas and buildings. The development proposals for the Northern Quarter include new housing, offices and an educational campus to be located within a forest setting and serviced by a new link road (see Appendix A).

1.1.2 Disused mining buildings within the Northern Quarter are used by a maternity colony of lesser horseshoe bats, which are a qualifying feature of the Wye Valley and Forest of Dean Bat Sites Special Area of Conservation (SAC) (Home and Communities Agency 2014). A substantial number of bat surveys have been undertaken within and around the Cinderford Northern Quarter site in the last 4-5 years to support the planning process. Outline planning permission was given in February 2015 (P0663/14/OUT, Forest of Dean District Council 2014) for the entire Northern Quarter area and in detail for a new spine road and college. In permitting the development the appropriate bodies have evaluated the likely impacts on bats and subsequent mitigation proposals, considering them acceptable.

1.1.3 We have been asked to develop a bat monitoring strategy to meet the requirements of condition 23 of the planning permission. Monitoring must be carried out to assess the impact of the development on the lesser horseshoe bat colony, and the effectiveness of the mitigation measures that are required by the planning permission. We have considerable experience working with bats, linear transport infrastructure and assessing mitigation measures (see Appendix E).

1.1.4 In the process of developing the strategy we have also been asked to review previous survey work to determine whether suitable baseline data exist for the purposes of future monitoring. In our experience, there is often a lack of suitable pre-construction data for developments such as this making it difficult, or even impossible, to reliably assess the impact of the scheme and the effectiveness of mitigation measures after construction. It is important that monitoring is considered at an early stage, before construction has commenced, so that sufficient and appropriately focussed baseline data can be collected that will allow comparisons to be made post-construction.

1.2 Outline of works

1.2.1 Overall objectives

- To develop a bat monitoring strategy to meet the requirements of condition 23 of permission P0663/14/OUT (the hybrid application) and to submit to the LPA to discharge the condition.

- To develop a monitoring strategy that will assess the effectiveness of mitigation features required by the planning permission and, if appropriate, trigger safeguards for corrective measures.

1.2.2 Scope

The strategy is to cover three main elements:

- Monitoring of the lesser horseshoe bat colony in the existing roosts (purpose-built, Northern United Office, Northern United Bath House)

- Monitoring of lesser horseshoe bats crossing the spine road

- Assessment of habitat use by lesser horseshoe bats in relation to off-site mitigation areas as detailed in the S106 document

1.2.3 Stages

The strategy is to be developed in three distinct stages:

<u>Stage 1 – Preliminary review</u>

Review existing data in relation to both the whole development site and the phase 1 areas (spine road from Steam Mills Road, crossing Old Engine Brook but not as far as Cinderford Brook, college site development and mitigation areas) and specifically address the following questions:

- Is the level of existing data sufficient to provide a baseline for future monitoring across both the whole development site and the phase 1 areas, proportionate to the level of use by lesser horseshoe bats?
- Is the level of existing data sufficient to provide a baseline for future monitoring across both the whole development site and the phase 1 areas, proportionate to the level of use by other species of bats?
- For future monitoring purposes if any gaps in baseline information become apparent, identify what options could potentially address the gaps and recommend any specific methodology requirements for the whole development site
- What would be an appropriate level of monitoring for phase 1 as a standalone development?
- What different approaches can be taken to monitoring phase 1 as a stand-alone project to monitoring the entire spine road when completed?
- To what extent will monitoring for lesser horseshoe bats address monitoring for other bat species and an indicator for habitat value more generally?

<u>Stage 2 – Monitoring Methodologies</u>

Develop appropriate detailed monitoring methodologies for each element of the scope (Roosts, Road, Habitats) which can be used as clear ‘instructions’ to those undertaking monitoring taking into consideration the length of the plan period to 2026. This is to include:

- Development of monitoring objectives
- Identification of baseline data requirements

- Identification of appropriate monitoring success criteria, thresholds, triggers and targets against which the effectiveness of mitigation can be judged
- Development of methods of data gathering and analysis including: locations of points/areas where monitoring will be undertaken; timing and duration of monitoring; data analysis and interpretation, responsible persons; lines of communication; review and publication of results/outcomes
- Development of rectification/adaptive management options that could be implemented if monitoring shows that measures are ineffective or are not reaching stated aims and objectives
- The monitoring methodologies are to cover both monitoring during construction and operation

Stage 3 – Consultation and finalisation

Review by Gloucestershire County Council/Forest of Dean District Council/Homes and Communities Agency and support consultation with Natural England.

2 PRELIMINARY REVIEW

2.1 Summary

Whole development site

2.1.1 Previous survey work has shown that the Cinderford Northern Quarter development site is frequently used by lesser horseshoe bats (and other bat species) and contains important resources for the lesser horseshoe bat maternity colony, including roosts, flightlines and foraging habitat. These findings have been useful in the planning process for considering the potential impact of the development and informing mitigation proposals. It is important that appropriate baseline data are also collected before construction to be able to assess the impact of the development on the lesser horseshoe bat colony in the future and the effectiveness of the mitigation measures proposed for bats.

2.1.2 The available population count data for lesser horseshoe bats are sufficient for detecting changes in colony size resulting from the development. We make recommendations to standardise these surveys in the future, and to collect additional information on colony productivity that could give an early warning of detrimental impacts. There are no population data (or appropriate abundance/activity measures) for other bat species using the development site in order to assess the impact on local colonies, and it would involve significant survey effort across a large area and extensive additional resources to collect such data, should it be required. The planning permission and associated Habitats Regulations Assessment has not identified any such requirement.

2.1.3 None of the survey work to date provides sufficient quantitative data for lesser horseshoe bats (or any other bat species) that can be used with future monitoring to assess the effectiveness of mitigation. We make recommendations for collecting baseline data to assess the effectiveness of the planned mitigation measures, including observational surveys along flightlines across the proposed spine road and automated recording within the habitat mitigation areas.

2.1.4 We discuss the role of bats as indicator species. The abundance of the lesser horseshoe bat population within the development site will, to some extent, reflect the quality of surrounding habitats and the status of other bat species. Detrimental impacts are likely to be detected earlier for lesser horseshoe bats as they are a sensitive, specialist species.

Phase 1 areas

2.1.5 Given the time constraints imposed by the construction schedule, we have agreed to consider phase 1 of the Northern Quarter as a standalone development in terms of the bat monitoring strategy, although we have advised of the potential impacts on survey data collected across the site in subsequent years. Previous survey work has shown the phase 1 construction and mitigation areas to be used infrequently by most bat species including lesser horseshoe bats, for which no roosts or major flightlines have been identified in these areas, although survey effort was low in comparison to the rest of the site. Baseline data must be collected for phase 1 of the development prior to construction commencing to be able to assess the impact of the development on the lesser horseshoe bat colony and the effectiveness of the mitigation measures proposed for bats.

2.1.6 The available population count data for lesser horseshoe bats are sufficient for detecting changes in colony size resulting from phase 1 of the development. There are no population (or appropriate abundance) data for other bat species using the development site in order to assess the impact on local colonies, and it would not be possible to collect such data prior to the scheduled construction start date, should it be required.

2.1.7 None of the survey work to date provides sufficient quantitative data for lesser horseshoe bats (or any other bat species) that can be used with future monitoring to assess the effectiveness of the mitigation strategies planned in phase 1 of the development. We have recommended the best possible strategy within the timeframe available to collect baseline data to assess the effectiveness of the mitigation planned for the phase 1 areas. This includes observational surveys along flightlines at the proposed locations for the wildlife underpasses and temporary brash corridors, and automated recording within the phase 1 mitigation areas. We also suggest additional surveys in other areas adjacent to the phase 1 development, which it would be advisable to carry out prior to construction commencing.

2.2 Responses to questions

Is the level of existing data sufficient to provide a baseline for future monitoring across both the whole development site and the phase 1 areas, proportionate to the level of use by lesser horseshoe bats?

2.2.8 Future monitoring is required to monitor any impact of the development on local bat populations and to assess the effectiveness of mitigation measures. We reviewed the existing survey work conducted across the whole development site, and separately in the phase 1 construction and mitigation areas, to determine whether sufficient baseline data exist for these purposes for lesser horseshoe bats.

<u>Previous survey work and the level of use by lesser horseshoe bats</u>

Whole development site

2.2.9 The Cinderford Northern Quarter is occupied by a maternity colony of lesser horseshoe bats, which are a qualifying feature of the Wye Valley and Forest of Dean Bat Sites SAC (Homes and Communities Agency, 2014). Previous survey work has confirmed the importance of the Cinderford Northern Quarter for this maternity colony with roosts, major flightlines and important foraging habitats identified within and around the development site. A range of survey techniques were employed across the site in 2011 and 2013, including building surveys, transects, trapping and radio-tracking, static logger surveys and fixed point count surveys (Kestrel Wildlife Consultants Ltd. 2011, AEWC Ltd. 2014). The existing lesser horseshoe maternity colony was recorded roosting in disused mining buildings (the Main Office and Bath House) at the Northern United Compound as well as in the nearby Hawkwell artificial bat roost (constructed in 2005). Radio-tracking surveys identified major flightlines crossing the proposed spine road in several places (see Appendix C), and core foraging areas within the development site and surrounding habitats (Figures 11-29 in AEWC Ltd. 2014). Lesser horseshoe bat activity was recorded during transects and static logger surveys across the development site, and was highest in areas adjacent to the existing roost locations (Kestrel Wildlife Consultants Ltd. 2011, AEWC Ltd. 2014).

Phase 1 areas

2.2.10 Survey work carried out in 2011 and 2013 found the phase 1 areas (including the construction and mitigation areas to the south) to be used infrequently by lesser horseshoe bats, with no major flightlines, roosts or foraging habitats identified within them (Kestrel Wildlife Consultants Ltd. 2011; AEWC Ltd. 2014). However, survey effort has often been lower in these areas than across the rest of the site. Despite a reduced survey effort, lesser horseshoe bat activity was consistently lower in the phase 1 areas relative to other areas of the development site. This is not unexpected given that these areas are furthest from the existing roosts used by the colony, there is poor quality habitat surrounding the construction area (large areas of scrub/open habitats) and the phase 1 areas are in close proximity to residential and industrial developments to the east.

2.2.11 Regardless of the lower levels of lesser horseshoe bat activity, various mitigation measures are being implemented for phase 1 of the development, and the extent of monitoring must be appropriate for the mitigation provided. It is therefore important that monitoring is sufficient to assess the impact of the phase 1 development and the effectiveness of the mitigation measures.

Monitoring local lesser horseshoe bat populations

Whole development site

2.2.12 The lesser horseshoe bat colony in the Northern Quarter has been counted every year since 2003, and monthly count data are available from mid-2012 (Forest of Dean District Council, pers. comm. July 2015). The current population data should be adequate to detect significant changes in colony size. However, the methods have changed over the years and should be standardised in future surveys to allow more reliable comparisons to be made. It would also be useful to collect more data on the reproductive success of the colony. Given the longevity of bats, there can be a considerable time lag between a disturbance and a subsequent reduction in colony size. Effects on reproductive success, however, become apparent sooner and provide an earlier indication of a detrimental impact on the colony.

Phase 1 areas

2.2.13 No lesser horseshoe bat roosts have been identified within the phase 1 areas, and the existing lesser horseshoe maternity colony is located over 500m away (Kestrel Wildlife Consultants Ltd. 2011; AEWC Ltd. 2014). The current population data should be sufficient for monitoring the phase 1 area, given that it is likely to have minimal impact on the lesser horseshoe bat colony.

Assessing the effectiveness of mitigation measures for lesser horseshoe bats

2.2.14 The existing survey results have been useful for identifying important lesser horseshoe bat habitats within the development site and for informing the placement of mitigation measures. However, monitoring must also be sufficient to assess the effectiveness of mitigation measures after construction. Quantitative data must be collected using standardised and systematic methods with sufficient frequency and intensity to reach reliable conclusions with regards to the success of each mitigation approach. However, previous surveys do not appear to have been designed with the specific purpose of forming a baseline for future monitoring, and have not been appropriately focussed to assess the planned mitigation. None of the current data are suitable for before and after construction comparison, and cannot be used to draw reliable conclusions about mitigation effectiveness. This applies to both the development site as a whole, and the phase 1 areas.

Is the level of existing data sufficient to provide a baseline for future monitoring across both the whole development site and the phase 1 areas, proportionate to the level of use by other species of bats?

Previous survey work and the level of use by other bat species

2.2.15 Understandably, much of the previous survey work in the Northern Quarter was focussed on the colony of lesser horseshoe bats, which are a qualifying feature of the Wye Valley and Forest of Dean Bat Sites SAC (Homes and Communities Agency, 2014). The bat monitoring strategy outlined in condition 23 of the planning permission (Forest of Dean District Council 2014) also refers specifically to lesser horseshoe bats, and we assume that future monitoring is not required for other bat species. However, other bat species were recorded in the Northern Quarter during surveys in 2011 and 2013 (Kestrel Wildlife Consultants Ltd 2011, AEWC Ltd. 2014) and therefore some consideration is given here.

2.2.16 Three other Annex II (Council Directive 92/43/EEC (1992) bat species were recorded within the development site (greater horseshoe bat, Bechstein's bat and barbastelle), and within or in close proximity to the phase 1 construction and mitigation areas. However, activity was low with occasional detections only. Although the methods used may have led to underestimates of particular species (e.g. *Myotis* bats were not identified to species during activity surveys), no important roosts for any of these species have been found within the Northern Quarter development site (Homes and Communities Agency 2014).

Whole development site

2.2.17 Transect surveys and static logger surveys for other species of bat show high levels of common pipistrelle activity across the whole development site. The results also suggest a significant level of use by soprano pipistrelles, brown long-eared bats, *Myotis* and *Nyctalus* species, and low levels of use by barbastelle, greater horseshoe bats and Nathusius' pipistrelles. Bat species with quiet echolocation calls, such as brown long-eared bats, are likely to be (and are often) under-represented in bat detector surveys. Levels of use by other bat species are generally as expected given the habitats present within the site and their typical prevalence within the wider landscape. No bat species other than lesser horseshoe bats were caught and tracked in 2011. In 2013, two bats of other species were tracked: one Natterer's bat was recorded foraging in various locations across the development site with a core foraging area to the south of the lake (Figure 30 in AEWC Ltd. 2014), and one Bechstein's bat was recorded with a core foraging area overlapping the south west corner of the development site (Figure 31 in AEWC Ltd. 2014). Survey effort was in most cases too low to provide an accurate, quantitative measure of activity that could be used for future monitoring purposes of other bat species.

Phase 1 areas

2.2.18 The phase 1 construction and mitigation areas appear to be used more frequently by other bat species than by lesser horseshoe bats. This is not unexpected given that habitats in the phase 1 areas are generally less suitable for lesser horseshoe bats than those in nearby areas. The use of the phase 1 areas by common pipistrelles was found to be higher on some occasions than in other areas of the development site. The survey results also suggest a significant level of use of the phase 1 areas by soprano pipistrelles, *Myotis* species and noctules, and low levels of use by brown long-eared bats, barbastelle, greater horseshoe bats and Nathusius' pipistrelles. However, survey effort was in most cases low and does not provide an accurate, quantitative measure of activity that could be used for future monitoring purposes.

Monitoring local populations of other bat species

2.2.19 No maternity colonies of other bat species have been found within the Northern Quarter development site or in the phase 1 construction and mitigation areas, although maternity colonies of

Bechstein's, Natterer's and noctule bats have been identified in the surrounding landscape (AEWC Ltd. 2014).

2.2.20 While surveying the existing lesser horseshoe bat roosts in buildings within the Northern Quarter compound, other bat species were reported to be using the roosts in low numbers in 2011 and 2013. During a dawn survey in 2011, four brown long-eared bats, one *Myotis* bat and one common pipistrelle were observed returning to roost in the buildings at the Northern United compound (Kestrel Wildlife Consultants Ltd. 2011). In 2013, low numbers of pipistrelles, Bechstein's and brown long-eared bats were using the buildings to roost (AEWC Ltd. 2014). Continued surveillance of the remaining buildings (some were demolished under licence in 2012), as well as new roost structures within the development area, could continue to document their use by other species if required.

2.2.21 There are no population count or activity data for any other bat species that use the Northern Quarter, which would be suitable as a baseline for future monitoring. Therefore, it will not be possible to assess the impact of the development on the favourable conservation status of bat species other than lesser horseshoe bats. If it is necessary to do so, this could be done by collecting comprehensive flight activity data from each species, from which levels of abundance can be inferred. Relative abundance levels can be compared before and after construction to provide a measure of population scale effects. This would need to be done across the whole development site and the surrounding landscape, and would require a significant amount of survey effort and resources. There would not be sufficient time to collect the volume of data that would be required prior to construction commencing in the phase 1 areas in late 2015. However, the planning permission has not identified any such requirement, and no bat species other than lesser horseshoe bats were subject to Habitat Regulations Assessment.

Assessing the effectiveness of mitigation measures for other bat species

2.2.22 As past surveys for other bat species followed the same methods as those used for lesser horseshoe bats, the same conclusions can be drawn for both the development site as a whole and for the phase 1 areas. Previous surveys do not appear to have been designed with the specific purpose of forming a baseline for future monitoring, and have not been appropriately focussed to assess the planned mitigation measures for any of the bat species present.

2.2.23 If future monitoring is required to assess the effectiveness of mitigation measures for other bat species, this could be carried out in conjunction with surveys for lesser horseshoe bats, for example within mitigation areas or at crossing structures. However, it should be noted that this would not provide a complete picture of effectiveness for other bat species without data on population sizes (or abundance) to demonstrate the overall impact of the development. As stated above, the planning permission has not identified this as a requirement for other bat species. The impact of the development is likely to be less for other bat species, given that no important roosts have been found within the site.

For future monitoring purposes if any gaps in baseline information become apparent, identify what options could potentially address the gaps and recommend any specific methodology requirements for the whole development site.

2.2.24 A brief overview of recommendations for monitoring across the development site is given below. The detailed survey methods are provided in section 3 of this report.

Monitoring local bat populations

Lesser horseshoe bats

2.2.25 Sufficient baseline data exist to assess the impact of the development on the size of the lesser horseshoe bat colony (assuming that emergence counts have been conducted in 2014 and 2015 in line with previous methods). However, standardised and systematic methods must be in place and continue to be used to ensure that comparisons can be made in subsequent years, and changes in the size of the colony can be accurately detected. Survey frequency must be sufficient to be able to detect significant changes in the size of the colony while accounting for natural variation across the season. Recommendations are provided in section 3.3.

2.2.26 To supplement these surveys, we also recommend additional data are collected to provide information on colony productivity. Given the longevity of bats, there can be a considerable time lag between a disturbance and a subsequent reduction in colony size. Effects on reproductive success, however, become apparent sooner and can provide an earlier indication of a detrimental impact on the colony. We suggest that the number of juveniles is counted during first emergence flights to give a basic estimate of the productivity of the maternity colony whilst minimising disturbance (see section 3.3 for full details). The data collected will monitor the impact of the development on the lesser horseshoe bat colony, and can also be used to assess the effectiveness of the purpose-built artificial bat roosts.

Other bat species

2.2.27 No notable bat roosts have been identified for other bat species recorded using the development area, and no population data (or appropriate abundance/activity measures) exist that can be used to assess the population-scale impacts of the development on other bat species. It should be noted that if this is necessary, significant survey effort and resources would be required to collect the large volumes of data needed for this prior to construction commencing. However, the use of any retained buildings, artificial roosts or bat boxes by other bat species could be recorded during monitoring for lesser horseshoe bats.

Assessing the effectiveness of mitigation measures

2.2.28 The recommended survey methods needed to provide baseline data to assess each of the main mitigation measures are described below. These methods can be used to collect data on the target species, lesser horseshoe bats, and also to simultaneously collect data on other bat species. It is essential that sufficient quantitative data are collected and that a standardised and systematic approach is used with a focus on consistency and repeatability.

Road crossings

2.2.29 Various mitigation measures have been proposed for bats crossing the new spine road (Homes and Communities Agency 2014). These include two culverts (Northern United culvert and Hawkwell culvert), two wildlife underpasses (at Cinderford Brook and Old Engine Brook in the phase 1 area) and at least one hop-over (within a dark corridor to the south of the junction with the A4136, more may be incorporated along the spine road). A bat bridge has also been proposed over the A4136 (Homes and Communities Agency 2014, Para 7.374g), and this location should be surveyed if the bridge is to be implemented. In order to assess the effectiveness of these structures, it is essential to collect quantitative baseline data for each of the flightlines to be mitigated, as well as for other unmitigated flightlines that will be severed by the road. We recommend baseline data are collected during at least one season (May to August inclusive) prior to construction.

2.2.30 We recommend surveys are carried out consisting of visual observations of flight behaviour at each location paired with echolocation call recordings for species identification, with methods similar to those used by Berthinussen and Altringham (2015). Observations consist of counts of commuting bats, with data on flight height, direction and distance from the linear habitat feature to be mitigated. A minimum of six 60 min dusk or dawn surveys should be carried out every year at each location, ideally between May and August. The number of bats crossing at each site will be compared before and after construction using simple statistical tests and boxplots, as will the number of bats using the mitigation structures, and the number crossing the scheme at risk of collision with traffic (at heights of <5 m above the road). Mitigation structures can be considered to be effective when bats are commuting across the scheme in similar numbers before and after construction, and at least 90% of crossing bats are using the structure to cross safely. See section 3.3 for the full monitoring methods and details on data analysis and interpretation.

Habitat creation and enhancement areas

2.2.31 Habitat creation and enhancement will be carried out to mitigate habitat loss within the development footprint (Homes and Communities Agency 2014). This will involve the replacement of conifer plantations with species-rich grassland, riparian habitats, shrub layers and mature stock broadleaved woodland, as well as the enhancement of existing woodland and grassland. There are six mitigation areas of varying size for the phase 1 area, and a further 11 mitigation areas for phase 2 of the development (see Appendix B). These mitigation areas vary in size from 0.1 ha to 6.89 ha and incorporate various combinations of the habitat improvements described above.

2.2.32 In order to assess the effectiveness of these mitigation areas, levels of bat activity must be compared before and after their construction. For enhanced or newly created habitats to be effective, they should support a significantly higher level of bat foraging activity than previously found in the area. It is therefore essential to collect quantitative baseline data for activity levels prior to any work commencing.

2.2.33 We recommend that automated detectors are deployed within each proposed mitigation area to collect quantitative baseline data on bat activity. Six automated detectors should be deployed for five consecutive nights per month between May and August (inclusive) along the proposed habitat interfaces within each of the mitigation areas. Detectors should be deployed at least 30 m apart. For small mitigation areas, the number of detectors may need to be reduced if the area is too small to place detectors at least 30 m apart. Prior to work commencing, detectors will be deployed in the existing habitats, e.g. conifer plantation, at locations that correspond with the edges of the proposed habitat improvements. Once habitats have been created or enhanced, surveys will be repeated with detectors deployed in identical locations along the newly created habitat interfaces. As some natural variation in bat activity is inevitable, sufficient data must be collected to allow changes resulting from the habitat improvements to be detected. We have suggested the use of automated detectors to monitor habitat use as they can be left to run unattended, and will require less input and resources than more intensive survey methods, such as transect surveys. Long term monitoring will be required, since habitats will take a considerable amount of time to become established. Full details of the monitoring methods are provided in section 3.3.

Night roost shelters, bat roosting and hibernation boxes

2.2.34 Bat roosting and hibernation boxes will be installed within some of the retained woodland surrounding the scheme to mitigate potential roost loss from habitat clearance. Two small night roost shelters will also be installed for lesser horseshoe bats. Baseline data prior to construction is not required for this mitigation measure, but the structures should be surveyed in subsequent years after installation to monitor use by lesser horseshoe bats and other bat species. See section 3.3 for details.

What would be an appropriate level of monitoring for phase 1 as a standalone development?

2.2.35 Phase 1 of the Cinderford Northern Quarter development consists of an area to the east of the scheme and will involve the construction of the spine road from Steam Mills Road to a point between Old Engine Brook and Cinderford Brook, as well as the development of the college site to the south of the spine road (see Appendix B). Construction of phase 1 is scheduled to commence in late 2015. Given the short time period available prior to construction, we have been asked to consider the phase 1 area as a standalone development in terms of the bat monitoring strategy.

2.2.36 Given these time constraints, the location of the phase 1 development area in relation to the existing lesser horseshoe bat roosts, the apparently infrequent use of the area by lesser horseshoe bats (discussed above) and the fact that site clearance and construction work will be outside of the active season for bats, we have agreed to consider phase 1 in isolation at this stage. However, it is important to point out that baseline surveys should ideally be carried out across the whole site prior to any construction works commencing. Habitat clearance and construction work in one area has the potential to change patterns of habitat use across a wider area, which may impact on data collected during surveys in subsequent years. This will be an important consideration if baseline data need to be collected across other areas of the development site.

2.2.37 Monitoring for bats at any site that is to be developed must be sufficient to identify habitats that are important to local bat populations, including roosts, foraging areas and commuting routes. Surveys must be carried out using appropriate methods, with sufficient frequency and intensity, to identify these resources and provide a quantitative measure by which to compare their use over time. This information is essential to inform the design and management of mitigation measures required to protect local bat colonies from any detrimental effects of the development.

2.2.38 Monitoring must be appropriate to generate suitable baseline data that can be used to assess the impacts of the development after construction and assess the effectiveness of mitigation measures. This allows for contingency plans to be put in place if the mitigation is not found to be effective enough, and provides important evidence that can be used to inform future mitigation efforts. In order to monitor the impact of the development and bat mitigation measures, it is essential that well documented (and therefore repeatable), standardised and systematic surveys are conducted both pre- and post-construction. Survey frequency and intensity must be sufficient to detect potential changes in both population sizes and the use of important resources (such as foraging habitat and flightlines). It is also important that surveys are designed to answer specific questions, and are conducted with sufficient duration and frequency to account for the temporal variation in activity commonly observed in bats.

2.2.39 The objectives of the monitoring for the Northern Quarter development as described in the Environmental Statement (Home and Communities Agency 2014, Para 7.385a) are "*to ascertain whether the proposed mitigation and compensation has been successful, to inform future management and to ascertain that the favourable conservation status of the bat populations has been maintained to ensure compliance is achieved*." This should apply both to the development as a whole and to the phase 1 development area.

2.2.40 Surveys to date have revealed that numerous bat species, including an important lesser horseshoe bat colony, use the development site to roost, forage and commute. However, most of the activity, especially for lesser horseshoe bats, appears to be concentrated away from the phase 1 area.

2.2.41 A number of mitigation measures for bats have been planned to reduce the impacts of the phase 1 development (Home and Communities Agency 2014). These include: 'wildlife underpasses' under the road at Old Engine Brook and Cinderford Brook; temporary brash corridors along Old Engine Brook and the eastern boundary of the Hamblett land; habitat creation and enhancement to the south of the development to mitigate habitat loss within the phase 1 development footprint; and bat roosting and hibernation boxes within habitats surrounding the phase 1 construction area and within the phase 1 mitigation areas.

2.2.42 Ideally, baseline data must be collected prior to construction in order to assess the effectiveness of all of the mitigation strategies for phase 1 of the development detailed above. Even if bat activity is reported to be low across the phase 1 site, it is still important (and a monitoring requirement) to assess the effectiveness of any mitigation measures that have been installed specifically for bats. The fact that mitigation was considered necessary for the phase 1 construction area indicates that detrimental effects on bats were anticipated, and therefore the effectiveness of the mitigation must be assessed. The level of monitoring required is not only dependent on the level of bat activity in the area but also on the mitigation, e.g. the Environmental Statement states that "*the extent of monitoring will need to be appropriate for the mitigation provided*" (Home and Communities Agency 2014, Para 7.385a). Quantitative data must be collected using standardised and systematic methods with sufficient frequency and intensity to reach reliable conclusions with regards to the success of each mitigation approach. However, given that bat activity is lower in this area and the majority of important resources appear to be concentrated in other areas of the development, monitoring of the phase 1 area will be less critical. It may be possible to reduce the level of monitoring required in order to work within the time constraints imposed.

2.2.43 Although we are considering the phase 1 area as a standalone development, it would also be advisable to collect baseline data to assess mitigation strategies in areas of the development that are adjacent to or in close proximity to the phase 1 areas prior to construction commencing. For example, the phase 2 woodland enhancement area to the north of phase 1 (see Appendix B) and the major lesser horseshoe bat flightline to the western edge of the lake (see Appendix C). As stated above, construction in the phase 1 area has the potential to impact on habitat use in surrounding areas (particularly those in close proximity), which could affect subsequent survey results, making it more difficult to accurately assess mitigation within these areas.

What different approaches can be taken to monitoring phase 1 as a stand-alone project to monitoring the entire spine road when completed?

Monitoring local bat populations

2.2.44 Sufficient data should exist to provide basic baseline data to assess the impact of phase 1 of the development on the lesser horseshoe bat colony (assuming that population counts have been conducted in 2014 and 2015 in line with previous methods). No notable bat roosts have been identified for other bat species recorded using the phase 1 development area, and no population (or appropriate abundance) data exist that can be used to assess the population-scale impacts of the development on other bat species. It should be noted that if this is required, there will not be sufficient time to collect the large volumes of data required for this prior to construction commencing.

Assessing the effectiveness of mitigation measures

2.2.45 For monitoring the effectiveness of mitigation measures, similar approaches will be used for the phase 1 areas and for the rest of the development. However, given that phase 1 of the development is likely to have minimal impact on the lesser horseshoe bat colony, it may be possible to reduce the level of monitoring in order to work within the time constraints imposed. Although not ideal, monitoring could be carried out late in the season and with a reduction in survey effort to allow some baseline data to be collected prior to construction commencing in the phase 1 area in late 2015. We recommend an increased level of monitoring for this area throughout the bat active season in subsequent years, in line with the rest of the development site (as detailed in section 3.3).

Wildlife underpasses

2.2.46 'Wildlife underpasses' with plantings and dark corridors will be installed below the road at Old Engine Brook and Cinderford Brook to provide a safe crossing point for bats and maintain connectivity on both sides of the road. In order to assess the effectiveness of the wildlife underpasses, it is essential to collect quantitative baseline data for these flightlines at the location of each underpass prior to construction. We recommend baseline data are collected during at least one season (May to August) prior to construction during six 60 min dusk or dawn surveys, as described above (see Para 2.2.30). Given the time constraints imposed by the development schedule, September may be acceptable for conducting surveys, but bat activity may be lower and behaviour may be atypical.

Temporary brash corridors

2.2.47 Temporary brash corridors will be put in place along Old Engine Brook and the eastern boundary of the Hamblett land, principally for Dormice mitigation, but it is acknowledged that it will also be a feature to mitigate potential habitat fragmentation and maintain connectivity for all bat species (until permanent measures are installed). Whilst this measure is not specifically identified within the Appropriate Assessment for lesser horseshoe bats, in order to assess effectiveness, it would be necessary to collect quantitative baseline data for the flightline to be mitigated at the location of the temporary corridor prior to construction. Baseline data for the temporary corridor can be collected using identical methods to those described for the road crossing mitigation (see Para 2.2.30). Surveys should be repeated in the same location and using the same methods during construction when the temporary corridor is in place, and also once the permanent measures (a new hedgerow) have been installed.

Habitat creation and enhancement areas

2.2.48 Habitat creation and enhancement is currently scheduled for late 2015 to mitigate habitat loss within the phase 1 development footprint (Home and Communities Agency 2014). There are six mitigation areas of varying size for the phase 1 area, with all but one (MP-1F) located in land to the south of the development site (Section 106 agreement 2015, see Appendix B):

- MP-1A: Conifer plantation will be removed (4.12 ha) and replaced with grassland (3.12 ha) and broadleaved woodland (1.09 ha), and two ponds will be created
- MP-1B: Conifer plantation will be removed (0.4 ha) and replaced with grassland
- MP-1C: Conifer plantation (0.61 ha) will be removed and replaced with grassland
- MP-1D: Existing woodland (0.31 ha) will be enhanced
- MP-1E: Existing woodland (0.12 ha) will be enhanced
- MP-1F: Grassland (0.59 ha) will be enhanced to the east of the phase 1 construction area

2.2.49 In order to assess the effectiveness of these mitigation areas, we recommend that automated detectors are deployed to collect quantitative baseline data on bat activity, as described above (Para 2.2.33). Ideally monitoring should be carried out throughout the active bat season. However, given the time constraints, data for the phase 1 mitigation areas could be collected in August and September only in 2015. If this is the case, surveys *must* be repeated during these months in subsequent years of monitoring so that direct comparisons can be made. Full details of the recommended monitoring methods are provided in section 3.3 of this report.

Bat roosting and hibernation boxes

2.2.50 Bat roosting and hibernation boxes will be installed within retained habitats surrounding the phase 1 construction area and within the phase 1 mitigation areas to mitigate potential roost loss from habitat clearance. Baseline data prior to construction is not required for this mitigation measure. Although not used by lesser horseshoe bats, the bat roosting and hibernation boxes could be surveyed in subsequent years to monitor use by other bat species. Further details are provided in section 3.3.

Additional survey work in other areas

2.2.51 As discussed previously, although we are considering the phase 1 area as a standalone development, it would also be advisable to collect baseline data to assess mitigation strategies in areas of the development that are adjacent to or in close proximity to the phase 1 areas prior to construction commencing. Construction in the phase 1 area has the potential to impact on habitat use in surrounding areas, which could affect subsequent survey results, hindering the ability to properly assess mitigation success within these areas.

2.2.52 For these reasons, we advise that surveys are carried out using the methods described above to collect baseline data for the proposed phase 2 mitigation area to the north of the phase 1 construction area (MP-2(R)D in Appendix B), and along the major lesser horseshoe flightline located on the opposite side of the lake to the college (flightline 2 in Appendix C). Although this monitoring is not essential if considering phase 1 as a standalone development, we advise that this is done to ensure that unbiased baseline data are collected for these areas also.

To what extent will monitoring for LHB address monitoring for other species and an indicator for habitat value more generally?

2.2.53 Bats make ideal indicators for the wider health of wildlife, habitats and ecosystems (Jones *et al*. 2009). They occupy high trophic levels, preying on common nocturnal insects, and are sensitive to a wide range of stressors that impact on other wildlife, such as changes in land use practices and urbanization. Bats have been used as ecological indicators of habitat quality (e.g. Wickramasinghe *et al*. 2003, Kalcounis-Rueppell *et al*. 2007), and eight UK bat species (including lesser horseshoe bats) are on the DEFRA (Department for Environment, Food and Rural Affairs) list of UK Biodiversity indicator species (DEFRA 2014). Lesser horseshoe bats, in particular, have specific habitat requirements and are often found in areas of high habitat diversity (Bontadina *et al*. 2002). The abundance of the lesser horseshoe bat population within the development site will, to some extent, reflect the status of insect communities and the quality of surrounding habitats. Monitoring this bat colony alongside other indicator taxa should provide a good picture of ecosystem health and habitat value.

2.2.54 The status of the lesser horseshoe bat colony will also, to some extent, reflect the status of other bat species found within the development site. The general habitat requirements for lesser horseshoe bats are important for many other bat species with a dependency on well-connected broadleaf woodland (Bontadina *et al.* 2002). Lesser horseshoe bats are a specialist species, and will be less tolerant of disturbance than generalists, such as common pipistrelles. They also typically fly slowly and at low heights (Russ 1999), making them more susceptible to collisions with traffic than faster, high-flying bat species. Detrimental effects of the development are, therefore, likely to be detected earlier for lesser horseshoe bats than for other less sensitive bat species. It will also be relatively easy to monitor the lesser horseshoe bat colony, given that the primary roost locations have been identified and are accessible for surveys of colony size and productivity. Monitoring the abundance of other bat species without access to known roosts would require large volumes of data to be collected across the development site and the surrounding landscape, requiring significant survey effort and resources each year. It would need to be decided whether this was necessary, given that no maternity roosts of other bat species have been identified within the development site. This requirement has not been identified in the planning permission and no other bat species were subject to Habitat Regulations Assessment.

3 MONITORING METHODS

3.1 Summary

3.1.1 We have provided recommendations for monitoring the lesser horseshoe bat colony in the Cinderford Northern Quarter to cover the three main scope elements (roosts, road and habitat) as summarised below.

3.1.2 To assess the impact of the development on the lesser horseshoe bat colony and the effectiveness of the artificial roosts, standardised monthly dusk emergence surveys should be conducted simultaneously (for two hours from 15 min prior to sunset) at the exit points of all known roost locations each year between May and August inclusive. These should be increased to weekly surveys at maternity roosts between mid-July and mid-August to record first flights of juveniles and provide an indication of colony productivity. We also suggest automated logging techniques for long term monitoring, such as infra-red motion detectors at roost access points.

3.1.3 To assess the effectiveness of crossing structures over/under the spine road, a minimum of six 60 min standardised dusk or dawn observational surveys should be carried out at the same time each year before (during at least one season), during and after construction between May and August at the location of each major lesser horseshoe bat flightline that will be severed by the new spine road or proposed location for a mitigation structure, if this does not coincide with a flightline.

3.1.4 To assess the effectiveness of habitat improvement or enhancement areas, six automated detectors should be deployed along the habitat interfaces of each mitigation area for five consecutive nights (sunrise to sunset) per month between May and August inclusive each year before (during at least one season), during and after construction.

3.1.5 We have focussed the monitoring strategy on the colony of lesser horseshoe bats, which are a qualifying feature of the Wye Valley and Forest of Dean Bat Sites SAC. If required, other bat species may be monitored alongside lesser horseshoe bats during surveys assessing the effectiveness of mitigation measures. It would, however, be difficult to collect sufficient data to assess the impact of the development on the population status of other bat species due to the lack of known roosts (this has not been identified as a requirement of the planning permission).

3.1.6 The recommended monitoring methods, if conducted consistently and to the specifications given, will provide sufficient quantitative data to successfully monitor the status of the lesser horseshoe bat colony and to assess the effectiveness of all planned mitigation measures against set thresholds. This will allow for adaptive management, if any of the mitigation is found not to meet these targets.

3.2 Overview and scope

3.2.1 Future monitoring is required to assess the impact of the Cinderford Northern Quarter development on the local lesser horseshoe bat colony, and to assess the effectiveness of bat mitigation measures. If the development is found to be having a detrimental impact and/or mitigation is not found to be effective enough, adaptive management and corrective measures may be required.

3.2.2 The preliminary review has identified a lack of suitable existing data that can be used as a baseline for future monitoring. Although existing survey results have been useful for identifying important lesser horseshoe bat habitats within the development site and for informing the placement of mitigation measures, they do not appear to have been designed with the specific purpose of forming a baseline for future monitoring, and have not been appropriately focussed to assess the planned mitigation. None of the current data are suitable for before and after construction comparison, and cannot be used to draw reliable conclusions about mitigation effectiveness. Quantitative data must be collected using standardised and systematic methods with sufficient frequency and intensity to reach reliable conclusions with regards to the success of each mitigation approach.

3.2.3 We have produced a monitoring strategy that has been designed to meet clearly defined objectives for each of the three monitoring elements detailed below. If repeated consistently and to the given specifications, the recommended surveys will provide sufficient quantitative data to assess the effectiveness of the planned mitigation measures in both meeting their basic function (e.g. providing safe crossing points over the spine road or improved foraging habitats in mitigation areas), and maintaining the favourable conservation status of the lesser horseshoe bat colony.

3.2.4 The monitoring strategy focusses on the lesser horseshoe bat colony, which is a qualifying feature of the Wye Valley and Forest of Dean Bat Sites SAC (Homes and Communities Agency, 2014). No notable roosts were found for other bat species within the development site, and monitoring for other bat species has not been identified as a requirement in the planning permission (Forest of Dean District Council 2014). If required, the effectiveness of mitigation measures for other bat species could be assessed simultaneously during surveys for lesser horseshoe bats. Determining the population effects on other bat species would, however, be difficult given the lack of known roosts and would require timely and labour intensive methods that may not be worthwhile given the levels of activity recorded.

3.2.5 As set out previously, the monitoring strategy must assess the effectiveness of mitigation features required by the planning permission, and is to cover three main elements:

1. Roosts - Monitoring of the lesser horseshoe bat colony in the existing roosts (purpose-built, Northern United Office, Northern United Bath House)

2. Roads - Monitoring of lesser horseshoe bats crossing the spine road

3. Habitat - Assessment of habitat use by lesser horseshoe bats in relation to off-site management as set out in the mitigation areas and S106 document

3.2.6 The monitoring objectives and methodologies for each of the three main elements are described in detail below. We provide recommendations for monitoring and assessing each of these elements individually. However, the results must also be considered collectively to provide a full understanding of the impacts on the colony and the effectiveness of the combined mitigation measures across the whole development site (see section 3.4 for further discussion of this).

3.3 Detailed survey methods and recommendations

Roosts: Monitoring the lesser horseshoe bat colony and the effectiveness of artificial roosts

Monitoring objectives

3.3.1 To monitor the impact of the Cinderford Northern Quarter development on the colony of lesser horseshoe bats present within the development site. This will be done by monitoring the size and productivity of the colony before, during and after construction. A significant decline of either will provide an indication of a negative impact.

3.3.2 To assess the effectiveness of the three purpose-built artificial roosts for lesser horseshoe bats (Hawkwell, Nelson and Birchwood Artificial Roosts). This will be done by monitoring the levels of use of these roosts by the lesser horseshoe bat colony.

Overview of survey methods

3.3.3 Sufficient baseline data exist to assess the impact of the development on the size of the lesser horseshoe bat colony (assuming that emergence counts have been conducted in 2014 and 2015 in line with previous methods). However, standardised and systematic methods must be in place and continue to be used to ensure that comparisons can be made in subsequent years, and changes in the size of the colony can be accurately detected. Survey frequency must be sufficient to be able to detect significant changes in the size of the colony while accounting for natural variation across the season.

3.3.4 To supplement these surveys, we recommend additional data are collected to provide information on colony productivity. Given the longevity of bats, there can be a considerable time lag between a disturbance and a subsequent reduction in colony size. Effects on reproductive success, however, become apparent sooner and can provide an earlier indication of a detrimental impact on the colony. We suggest that the number of juveniles is estimated during first emergence from the roost to give a basic estimate of the productivity of the maternity colony whilst minimising disturbance (see below).

Detailed survey guidelines

3.3.5 Our recommendations for monitoring the lesser horseshoe bat colony are to conduct dusk emergence surveys at the same time each month between May and August inclusive at all potential lesser horseshoe bat roosting locations (the Main Office and Bath House until demolition, Hawkwell artificial bat roost and the two newly constructed artificial roosts, Nelson and Birch Wood). We suggest monthly surveys are conducted during the first three years after construction. If the colony is stable after this time, the survey interval could be re-assessed.

3.3.6 All locations and all access points must be monitored simultaneously to account for roost switching between nights and ensure accurate counts of the colony are made. Investigative day time surveys of buildings should also be carried out several times each year between May and August across the site to check for other newly adopted roosting locations. If new roosts or access points are discovered, these should be included in the surveys. This is especially important if the number of bats begin to decrease, to determine whether there has been a reduction in colony size, or whether the bats have moved to other roosting locations within the development site. Ideally emergence surveys should be continued at all roosting locations, unless they are permanently abandoned by the colony. However, if any roosting location is used by only a small proportion of the colony over two or more years (e.g. less than 5% of the total colony), emergence surveys could be replaced with internal day counts on the same day as emergence surveys at the other roost sites.

3.3.7 Surveys should be conducted from 15 min prior to sunset for two hours in good weather conditions (temperature >7°C, wind <20 km/h, no rain). Weather variables, including wind, temperature and percentage cloud cover, should be recorded at the beginning, middle and end of each survey. If conditions deteriorate during a survey, it should be abandoned and repeated on a subsequent evening when conditions improve.

3.3.8 A sufficient number of surveyors (equipped with full spectrum bat detectors or heterodyne detectors tuned to 110 kHz) should be used to observe all locations and exit points. For sites that are difficult to monitor, e.g. with poor visibility and/or surrounded by dense vegetation, a night vision camera with infra-red (IR) lights could also be used. Multiple cameras could be set up to run independently and monitor all access points, but this will depend on the budget and the nature of each site. The same equipment should be used for all surveys and in subsequent years as the ability to detect and count bats may vary between methods (e.g. surveyor vs camera). All lesser horseshoe bats emerging from the roost should be counted. A tally-counter can be used to quickly count and record large numbers of bats as they emerge.

3.3.9 Disturbance should be minimised during emergence counts. Surveyors should be close enough to the roost entrances to observe and detect bats emerging, but not so close as to disturb bats or obstruct their flight paths. Surveyors should remain quiet and refrain from using torches, using red filters only if this is unavoidable.

3.3.10 In July and August, the number of juveniles within each roost should be estimated to provide information on colony productivity. To minimise disturbance, we recommend this is done by conducting frequent emergence counts during this period to record the first flights of juveniles, when the number of bats emerging would be expected to increase quickly. We suggest weekly counts from mid-July to mid-August.

3.3.11 All methods must be thoroughly documented in sufficient detail to allow surveys to be repeated consistently in subsequent years. We recommend the colony is monitored for at least ten years after construction.

3.3.12 If the majority of the lesser horseshoe bat colony eventually use the artificial roosts, permanent automated logging techniques could be considered as a long term and less labour intensive method to monitor the colony. Automated bat detectors could be used at roost entrances to detect and record lesser horseshoe bats entering or exiting the roost, although this would provide an index of activity only and not a count of individual bats. Another option is to position infra-red motion detectors across the roost entrances of the artificial roosts. The motion detectors log bats as they pass through infra-red beams positioned across the roost entrance. Relatively accurate methods have been developed using active sensors that reduce the risk of false triggers, e.g. by birds or other animals, and multiple beams can be used to determine the direction of flight and whether bats are exiting or entering the roost (Hope and Jones 2013). These techniques have been used successfully at lesser and greater horseshoe bat roosts in Wales to provide counts of minimum colony size (Payne 2014). If these methods are to be adopted, we suggest running them in parallel with the survey methods described above for at least two years as the results from different methods will not be directly comparable.

Data analysis and interpretation

3.3.13 The data collected from the above surveys will consist of counts of emerging bats. Between May and mid-July, female bats will arrive at maternity roosts and give birth to and suckle their young, which are unable to fly (pre-volant period). Emergence counts during this period should provide an indication of the number of adult females within the colony. Between mid-July and mid-August, juvenile bats are weaned and make their first flights outside of the roost (post-volant period). Emergence counts are likely to increase quickly during this period, and the increase in number will provide an indication of the number of juveniles within the roost. A basic measure of colony productivity (or reproductive success) can be calculated by dividing the number of juveniles by the number of adult females to determine how many females successfully reproduced in that season. One juvenile per female is considered to be 100% reproductive success.

3.3.14 For an overall view of colony size and productivity, the counts from all roost locations may be added together for each survey, and the following values noted:

a) Maximum total colony count recorded during pre-volant period (May to mid-July)
b) Maximum total colony count recorded during post-volant period (mid-July to mid-August)
c) Estimated number of juveniles = (b – a)
d) Reproductive success (%) = (c / a) x 100

3.3.15 To visualise trends, multiple years of data for a) and c) could be plotted on a line graph with 'year' on the x axis, and counts on the y axis. Reproductive success (d) could also be plotted on a separate line graph for multiple years of survey.

3.3.16 The variables above should also be calculated individually for each artificial roost that is surveyed, so that roosting and productivity within each of the artificial roost buildings can be assessed. Line graphs for multiple years of data for each building can be plotted as above.

Detecting a negative impact

3.3.17 A significant decline in colony productivity and/or colony size would indicate that the development is having a negative impact on the lesser horseshoe bat colony. There is likely to be some natural variation in the size and productivity of the colony from year to year. We suggest a decline of >10% in two consecutive years is cause for concern. We might expect to detect a decline in colony productivity before a decline in colony size becomes apparent, unless all or part of the colony abandoned one or more of the roosts, but a reduction of either variable should be checked. The most recent data on colony size and productivity from the year before construction commenced should be used as a baseline.

Assessing the effectiveness of the artificial roosts

3.3.18 Given that original roosting buildings will be demolished, we suggest that the artificial roosts (Hawkwell, Birchwood and Nelson) can be considered to be effective when they are collectively used by most of the lesser horseshoe maternity colony each year (we suggest >90%), *and* the overall colony size and productivity remain stable or increase. If any of the artificial roost buildings are not used by the maternity colony after three years, it would be worth comparing successful and unsuccessful roost microclimates to guide possible roost modification. Long term monitoring is important, as bats may take some time to adapt to the new roost locations.

Night roost shelters, bat roosting and hibernation boxes

3.3.19 Bat roosting and hibernation boxes will be installed within some of the retained woodland surrounding the scheme to mitigate potential roost loss from habitat clearance. Two small night roost shelters will also be installed for lesser horseshoe bats. Baseline data prior to construction is not required for these mitigation measures, which are designed to provide additional facilities in the foraging areas. The night shelters should be monitored for use by lesser horseshoe bats after installation, and although not suitable as roosts for lesser horseshoe bats, the bat boxes could be surveyed to monitor use by other bat species. This should be done ideally by conducting monthly daytime checks of the boxes in May, July, August and September (avoiding June when pups may be present), but a single inspection for evidence of use (bats or bat droppings) in July or August will provide basic data on usage. Unnecessary disturbance and handling of bats should be avoided during box/night roost checks. Use of the bat boxes by birds should also be recorded as this may affect bat occupancy levels (e.g. Meddings *et al*. 2011).

Roads: Assessing the effectiveness of mitigation measures for bat flightlines crossing the road

Monitoring objectives

3.3.20 To assess the effectiveness of mitigation measures that have been proposed for bats crossing the new spine road (listed below). To be effective, the crossing structures should maintain connectivity between habitats for commuting bats and minimise the potential for collision mortality, with the overall aim of maintaining the favourable conservation status of the local lesser horseshoe bat colony.

3.3.21 The survey methods below produce quantifiable data that can be used to determine whether the structures are guiding commuting bats safely over or under the road and, when repeated before and after construction, whether there has been any change in the number of bats using a commuting route.

3.3.22 The recommended survey methods needed to provide baseline data to assess each of the main mitigation measures are detailed below. These methods can be used to collect data on the target species, lesser horseshoe bats, and also to simultaneously collect data on other bat species. It is essential that sufficient quantitative data are collected and that a standardised and systematic approach is used with a focus on consistency and repeatability.

Overview of survey methods

3.3.23 Proposed mitigation measures (see Homes and Communities Agency 2014) that will require monitoring:

- Northern United culvert
- Hawkwell culvert
- Cinderford Brook wildlife underpass (phase 1 area)
- Old Engine Brook wildlife underpass (phase 1 area)
- Hop-overs (at least one has been proposed within a dark corridor to the south of the junction with the A4136, more may be incorporated along the spine road)
- A4136 bat bridge (if implemented)

3.3.24 In order to assess the effectiveness of these mitigation structures, it is essential to collect quantitative baseline data before construction for each of the flightlines to be mitigated, as well as for other unmitigated flightlines that will be severed by the road.

3.3.25 The basic survey consists of visual observations of flight behaviour at each location paired with echolocation call recordings for species identification, with methods similar to those used by Berthinussen and Altringham (2015). Observations consist of counts of commuting bats, with data on flight height, direction and distance from the linear habitat feature to be mitigated (before construction), or the mitigation structure (after installation).

3.3.26 The number of bats crossing at each location should be compared before and after construction using simple statistical tests and boxplots, as should the number of bats using the mitigation structures, and the number crossing the scheme at risk of collision with traffic (at heights of <5 m above the road). Mitigation structures can be considered to be effective when bats are commuting across the scheme in similar numbers before and after construction, and at least 90% of crossing bats are using the structure to cross safely.

Detailed survey guidelines

Before construction

3.3.27 Surveys should be conducted before construction (during at least one season) at the location of each lesser horseshoe bat flightline that will be severed by the road (i.e. flightlines 1A, 1B, 1C, 2, 3 and 4 in Appendix C), and at the proposed location of each crossing structure if this does not coincide exactly with a flightline. Although flightline 3 does not cross the proposed spine road, it is important that it is monitored to provide a complete picture of commuting activity from the lesser horseshoe bat maternity roost, and to assess the effectiveness of the proposed bat bridge over the A4136 (if implemented).

3.3.28 A minimum of six 60 min dusk or dawn surveys (commencing either at sunset or one hour before sunrise) should be carried out at each location, including at least three at dusk, to account for night to night variability in bat activity patterns. Surveys should be conducted between May and August inclusive in good weather conditions (temperature >7°C, wind <20 km/h, no rain). September may be acceptable (e.g. for surveying the phase 1 sites within the time constraints of the construction schedule) but bat activity may be lower and behaviour may be atypical. If conditions deteriorate during a survey, it should be abandoned and repeated on a subsequent evening when conditions improve.

3.3.29 Two surveyors are recommended, with both surveyors positioned along the existing flightline or proposed crossing structure location, one on each side of the proposed road, facing towards each other. For flightlines along a wide habitat feature (e.g. a strip of woodland), more surveyors and bat detectors may be required to ensure that activity is not missed, or surveys could focus on narrower pinch points if they correspond with the crossing location. This will need to be determined by surveyors on the ground at each site. The number and position of surveyors and detectors must be thoroughly documented to ensure that methods can be repeated precisely in subsequent years.

3.3.30 Each surveyor should be equipped with a data recording sheet, heterodyne bat detector set to an audible volume to alert the surveyor to the presence of a bat and tuned to the appropriate frequency for the bat species of interest (e.g. 110 kHz for lesser horseshoe bats, 45 kHz for other bat species), a suitable bat detector and recording device set to automatically detect and record bat echolocation calls (we recommend full spectrum methods for high quality recordings of all bat species), and optional additional automated detectors placed along the flightline to aid species identification. An example datasheet has been provided in Appendix D. Site maps or diagrams may also be useful for quick reference to compass bearings during surveys, and for annotating with surveyor positions etc.

3.3.31 To accurately judge flight heights and distances, marker poles may be erected (e.g. we use lightweight telescopic fishing net handles with clip-on red LED battery bicycle lights at 1 m intervals). Alternatively, measurements can be taken in the survey area and reference points used (such as the height and distance of fixed physical landmarks such as road signs, fencing, road markings etc.). Either way, surveyors should be confident that they can quickly and consistently estimate heights and distances to the nearest metre if the bat is flying <5 m from the ground.

3.3.32 Each surveyor should record observations of all commuting bats during the survey, including details on flight height, direction and distance from the habitat feature/flightline to be mitigated (to the nearest metre). The time of each observation must be recorded accurately (ideally to the nearest second), and the time should be taken from the bat detector/recorder or a watch/clock synchronised with it. This will allow each observation to later be paired with echolocation call recordings for species identification. Each commuting bat flying across the proposed location of the road should be recorded as a separate observation, regardless of whether the same bat has crossed more than once.

<u>During/after construction</u>

3.3.33 Surveys should be repeated, following identical methods to those described above, at each location both during and after construction. Where a temporary or permanent mitigation structure has been installed, surveyors will also record the distance of commuting bats from the structure (to the nearest metre). We recommend surveys are repeated annually for a minimum of three years post-construction. If mitigation is found to be effective and the lesser horseshoe colony is stable or increasing, surveys could then be conducted in years 5, 7 and 10 post-construction to confirm longer term stability. If mitigation is found to be failing and the colony is decreasing, annual surveys should be continued until this is rectified.

3.3.34 The same number of dusk and dawn surveys must be completed at the same time of year at each site in subsequent years of monitoring to allow for accurate comparison. If possible, the same team of surveyors (with the same equipment) should conduct the repeat surveys to eliminate any variation due to observer and equipment bias.

3.3.35 The same number of surveyors should be used as in the previous surveys. However, where underpasses or culverts have been installed one surveyor should be positioned at one end of the underpass/culvert to record bats flying through it, and one surveyor should be positioned on one side of the road above to record bats flying over the road.

<u>Data analysis and interpretation</u>

3.3.36 Records of observations from all surveyors should be combined and duplicates removed. Each bat that was observed should be identified to species (if this was not possible in the field) by referring to the echolocation calls recorded at the exact time of the observation. This could be done by visually inspecting sonograms using software, such as Batsound Pro (www.batsound.com), or by using automated identification software, such as BatClassify (www.bitbucket.org/chrisscott/batclassify).

Observations of species other than lesser horseshoe bats should be removed from the dataset (and analysed separately if required).

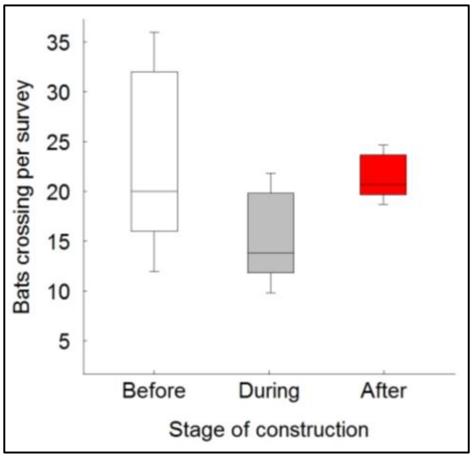
3.3.37 To determine the effectiveness of the mitigation, we need to determine whether the crossing structure is effectively maintaining connectivity so that bats can continue to use commuting routes and habitats in the surrounding landscape as they did prior to construction, *and* if it is guiding bats safely over or under the road minimising the risk of mortality through collisions with traffic. Therefore, the effectiveness of each crossing structure is assessed by both of the following questions:

1) Are similar numbers of bats using the commuting route both before and after construction and installation of the crossing structure?

2) Are at least 90% of bats using the crossing structure crossing the road safely?

Are similar numbers of bats using the commuting route both before and after construction and installation of the crossing structure?

3.3.38 To answer this question, the total number of lesser horseshoe bats crossing per survey should be calculated before construction (the baseline data). This can then be compared to the total number of bats crossing per survey in subsequent years e.g. during or after construction. To visualise the data, boxplots can be produced to show the median number of crossing bats per survey during each stage of construction, as well as the variance in the data (see below).



Example boxplot showing the median (with upper and lower quartiles) of the number of bats crossing per survey before, during and after construction.

3.3.39 Comparisons can be made between any two years of data or stages of construction (e.g. before, during or after) using a simple statistical test, the Wilcoxon signed rank test. This can be carried out in most statistical programs, such as SPSS and R. A *P* value of less than 0.05 indicates that the difference in activity between the two years has only a 5% probability of occurring by chance and can be assumed to be a real change in activity. The percentage change in the number of bats using the commuting route can also be calculated from the totals.

Are at least 90% of bats using the crossing structure crossing the road safely?

3.3.40 We recommend the following set definitions are used to determine whether bats are 'using' a mitigation structure to cross the road, or are crossing the road at 'safe' or 'unsafe' heights (Berthinussen & Altringham 2015).

- Use of the mitigation structure
  Over the road structures: bats crossing the road within 5 m of the crossing structure and at a safe height (over 5 m above the road)
  Underpasses: bats flying through the underpass to cross the road

- Safe / unsafe crossing heights
  'Safe' and 'unsafe' crossing heights are defined as being greater and less than 5 m above the road surface respectively. Bats crossing the road below a height of 5 m are considered to be at risk of being killed by passing traffic.

3.3.41 Using the definitions above, the total number of bats crossing the road for each of the following across all surveys after construction should be calculated:

a) The total number of crossing bats

b) The total number of bats crossing 'using' the mitigation structure
= the number of bats crossing at a horizontal distance of less than 5 m from the structure and at a height between 5 m above the road and 5 m above the structure

c) The total number of bats crossing the road unsafely
= the total number of bats crossing the road at a height of 5 m or less

3.3.42 These totals could be presented in a table as well as a boxplot to visualise the data. To assess effectiveness, percentages for each crossing behaviour should also be calculated from the totals above.

3.3.43 Detailed instructions and code for carrying out all of the above analysis in the R program are given in our Defra report WC1060 (Berthinussen & Altringham, 2015).

Drawing conclusions

3.3.44 The results from the analysis for Q1 and Q2 above are used to assess the effectiveness of each mitigation structure.

3.3.45 For a crossing structure to be effective, a similar number of bats must be using the commuting route before and after construction, and at least 90% of bats must be 'using' the structure to cross the road safely. If either of these criteria are not met, then the crossing structure cannot be considered to be effective.

3.3.46 If the number of bats using the commuting route has declined substantially since construction then the mitigation structure cannot be considered to be effective. A statistically significant decline of 10% or more suggests a non-effective crossing point. A decline of more than 20% that is not statistically significant suggests that more data are required to reach a reliable conclusion. Either the road is acting as a barrier to commuting bats, bats are crossing the road at other locations, or the number of bats in the colony has declined since road construction (this would be revealed by monitoring the colony). Either scenario implies failure of the mitigation structure in question.

3.3.47 If less than 90% of bats are using the crossing structure and more than 10% of bats are crossing the road unsafely, then the number of bats potentially being killed through traffic collision mortality is likely to have a detrimental impact on the bat colony.

3.3.48 If less than 50% of bats are using the crossing structure, but less than 10% of bats are crossing the road unsafely, the structure is still ineffective as it is not being used by the majority of bats to cross the road. However, as the majority of bats are crossing the road at a safe height in this scenario, it may be that the crossing structure is not needed. If this scenario does occur then careful site-specific consideration would be needed. It may be that other aspects of the site are increasing the flight height of crossing bats, such as elevated verges or tall trees approaching the road, and these would need to be maintained. Or it may be that bats are choosing to cross at other more suitable crossing points. Considerable monitoring and understanding of the site would be needed before any changes are made, or crossing structures removed.

3.3.49 Other scenarios are also clearly possible, and the results must be given careful consideration. Although we suggest that mitigation structures are assessed individually as above, it will also be important to review the results from all crossing structures collectively. The movement of lesser horseshoe bats across the development site may change during and/or after construction with different numbers of bats using different crossing points, and the results from all crossing structures will be needed to understand site-wide changes and impacts. **Overall, the total number of lesser horseshoe bats crossing the spine road at risk of collision mortality should be < 10% of the total colony size.** Potential increases in mortality above this level may have a detrimental impact on the colony.

Temporary brash corridors

3.3.50 Temporary brash corridors will also be put in place along Old Engine Brook and the eastern boundary of the Hamblett land. Although principally designed as mitigation for Dormice, it is acknowledged that the corridors may also mitigate potential habitat fragmentation and maintain connectivity for all bat species (until permanent measures are installed). Whilst this measure is not specifically identified within the Appropriate Assessment for lesser horseshoe bats, in order to assess effectiveness, it would be necessary to collect quantitative baseline data for the flightline to be mitigated at the location of the temporary corridor prior to construction.

3.3.51 Baseline data for the temporary corridor can be collected using identical methods to those described above, with surveyors positioned along the existing flightline at the location of the proposed temporary corridor. Surveys should be repeated in the same location and using the same methods during construction when the temporary corridor is in place, and also once the permanent measures (a new hedgerow) have been installed. Effectiveness of these mitigation measures could be assessed using methods similar to those for other flight path mitigation (e.g. by answering Q1 in the analysis section above).

Habitat: Assessing the effectiveness of habitat creation and enhancement areas for bats

Monitoring objectives

3.3.52 To assess the effectiveness of habitat creation and enhancement in mitigation areas for foraging bats. To be effective, habitat mitigation areas should support a significantly higher level of bat foraging activity than previously found in the area, with the overall aim of maintaining the population size of the local lesser horseshoe bat colony.

3.3.53 The recommended survey methods needed to provide quantitative baseline data to assess each of the habitat mitigation areas are detailed below. These methods can be used to collect data on the target species, lesser horseshoe bats, and also to simultaneously collect data on other bat species. It is essential that sufficient quantitative data are collected and that a standardised and systematic approach is used with a focus on consistency and repeatability.

Overview of survey methods

3.3.54 Habitat creation and enhancement will be carried out to mitigate habitat loss within the development footprint (Homes and Communities Agency 2014). This will involve the replacement of conifer plantations with species-rich grassland, riparian habitats, shrub layers and mature stock broadleaved woodland, as well as the enhancement of existing woodland and grassland. There are six mitigation areas of varying size for the phase 1 area, and a further 11 mitigation areas for phase 2 of the development (see Appendix B). These mitigation areas vary in size from 0.1 ha to 6.89 ha and incorporate various combinations of the habitat improvements described above.

3.3.55 Automated detectors should be deployed within each proposed mitigation area to collect quantitative baseline data on bat activity. Surveys should be repeated after the habitats have been created or enhanced for comparison. As some natural variation in bat activity is inevitable, sufficient data must be collected to allow changes resulting from the habitat improvements to be detected. We have suggested the use of automated detectors to monitor habitat use as they can be left to run unattended, and will require less input and resources than more intensive survey methods, such as transect surveys. Long term monitoring will be required as habitats will take a considerable amount of time to become established. We recommend annual surveys are repeated for a minimum of 10 years post-construction. If this survey frequency is not possible, annual surveys could be conducted for the first three years followed by biennial surveys, although this may make it more difficult to detect trends, assess effectiveness and implement adaptive management.

Detailed survey guidelines

3.3.56 Six automated detectors should be deployed at least 30 m apart along habitat interfaces, such as grassland, woodland and wetland edge (or proposed location of habitat interfaces prior to construction) within each planned habitat mitigation area. Bat activity is likely to be highest and more appropriate for monitoring within these edge habitats. For small mitigation areas, the number of detectors may need to be reduced if the area is too small to place detectors at least 30 m apart.

3.3.57 Prior to construction work commencing, the detectors will be deployed in the existing habitats e.g. conifer plantation, at locations that correspond with the edges of the proposed habitat improvements. For example, in mitigation area MP-2(F)A, two detectors should be deployed along the location corresponding to the edge of the grassland enhancement area, two along the location corresponding to the proposed new woodland edge, and one detector on the proposed edge of two of the small pond sites. For mitigation areas with only one type of habitat improvement (e.g. MP-2(R)A where 2.43 ha of conifer plantation will be replaced with grassland), all six detectors would be deployed along the location corresponding to the grassland edge. Once mitigation areas are created, detectors will be deployed in the same locations along the newly created habitat interfaces.

3.3.58 Detectors should be installed at a height of approximately 1.5 - 2 m above the ground with the microphone aligned horizontally, and set to automatically detect and record bat echolocation calls from sunset to sunrise. The date, start and finish time of all surveys must be recorded, as well as the exact location of the detector. Each detector should be left to record for five consecutive nights per month between May and August inclusive. Surveys must be repeated at approximately the same time within each month in subsequent years of monitoring so that direct comparisons can be made.

3.3.59 An identical brand and model of bat detector set with identical settings must be used for all surveys and for all future repeats. Detailed notes must be made about the detectors and *all* settings used to ensure consistency in future surveys. We recommend full spectrum bat detectors e.g. the Pettersson D500x (www.batsound.com), to maximise the volume of data that can be collected and to ensure high quality recordings of all bat species.

3.3.60 Ideally, surveys should only be done in 'good' weather, avoiding periods of prolonged heavy rain, strong winds or low temperatures that may influence bat activity levels. Short periods of inclement weather during the five nights of recording should not impact the overall results.

3.3.61 All data must be regularly downloaded and backed up for later analysis.

Data analysis and interpretation

3.3.62 All bat echolocation calls recorded during the above surveys must be identified to species. We recommend that this is done using automated identification software, such as BatClassify (www.bitbucket.org/chrisscott/batclassify), as large numbers of calls are likely to be recorded. Observations of species other than lesser horseshoe bats should be removed from the dataset (and analysed separately if required).

3.3.63 To determine the effectiveness of a mitigation area, we need to know if it supports a significantly higher level of bat foraging activity than before it was created or enhanced. The data collected during the year (or more) before construction commenced should be used as a baseline for bat activity in each mitigation area. The total number of lesser horseshoe bat passes recorded within a mitigation area must be counted for each recording per survey. A single bat pass can be defined as: one or more clearly recognisable echolocation calls from a single species, separated from the next pass by a gap of at least 1 second. The totals should be entered into a spreadsheet for each mitigation area with the survey results in chronological order. Columns of data can be added for repeat surveys in subsequent years, e.g. during or after construction, again in chronological order. To visualise the data, boxplots could be produced for each mitigation area to show the median number of bat passes per survey during each year or stage of construction, as well as the variance in the data (see earlier example).

3.3.64 Comparisons can be made between any two years of data or stages of construction (e.g. before, during or after) using a simple statistical test, the Wilcoxon signed rank test. This can be carried out in most statistical programs, such as SPSS and R. A *P* value of less than 0.05 indicates that the difference in activity between the two years has only a 5% probability of occurring by chance and can be assumed to be a real change in activity. The percentage change in the number of bat passes recorded in the mitigation area can also be calculated from the totals.

Drawing conclusions

3.3.65 A mitigation area can be considered to be providing effective mitigation for the loss of foraging habitat, when lesser horseshoe bat activity levels are higher in the area than previously found before habitat creation or enhancement was carried out. Some natural variation in bat activity is expected between years. We suggest a statistically significant increase in lesser horseshoe bat activity over two or more years shows that the habitat mitigation areas are effective. If there is no statistically significant change in bat activity levels, or activity decreases, the mitigation areas cannot be considered to be effective. Long term monitoring (for at least 10 years) is advisable as habitats will take some time to become established, and bats may take time to adapt to them.

3.4 Adaptive management

3.4.1 We provide recommendations for monitoring and assessing each mitigation measure individually. However, the results must also be considered collectively to provide a full understanding of the impacts on the lesser horseshoe bat colony and the effectiveness of the combined mitigation measures across the whole development site. Bat behaviour may change across the development site after construction. For example, the number of bats using a flight path could decrease significantly if the majority of bats switch to using an alternative flight path, but this may not necessarily result in a detrimental impact on the colony. It is important to closely monitor the bat colony as well as changes in bat behaviour across the site, and the effectiveness of mitigation measures. Using the methods recommended above, it is likely that a failing mitigation feature would be detected quickly (e.g. a crossing structure that is not preventing traffic collision mortality), whereas changes in colony size may take several years or more to become apparent.

3.4.2 If any of the mitigation measures are found to be failing and/or negative impacts on colony size or productivity are detected, corrective measures may be required. This could include additional planting or screening, removal of lighting or imposing light restrictions, further habitat improvements, modification of existing crossing structures or installation of new structures, improving access to or modifying conditions within artificial roosts etc. We are unable to provide specific recommendations for such measures at this stage, as the most appropriate course of action will depend on the specific scenario at the time. Corrective measures such as these must be given careful site-specific consideration and relevant experts should be consulted. From our experience and the evidence available, retrofitting or adapting mitigation post-construction is often ineffective and considerable damage is already likely to have been done at that stage. It is important that mitigation is designed to be as effective as possible from the outset.

References

AEWC Ltd. (2014) *Bat survey Northern United Cinderford*. Animal Ecology & Wildlife Consultants, Petworth, Sussex.

Berthinussen, A. & Altringham J. (2015) *WC1060: Development of a cost-effective method for monitoring the effectiveness of mitigation for bats crossing linear transport infrastructure.* Final report to Defra. Available at http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=18518.

Bontadina, F., Schofield, H. & Naef-Daenzer, B. (2002) Radio-tracking reveals that lesser horseshoe bats (*Rhinolophus hipposideros*) forage in woodland. *Journal of Zoology,* **258**, 281-290.

Council Directive 92/43/EEC (1992) *Conservation of Natural Habitats and of Wild Fauna and Flora*. Brussels, EU.

DEFRA (2014) *UK Biodiversity Indicators 2014: Measuring progress towards halting biodiversity loss*. Retrieved from http://jncc.defra.gov.uk/pdf/UKBI2014.pdf

Forest of Dean District Council (2014) *P0663/14/OUT decision notice.*

Kalcounis-Rueppell, M. C., Payne, V. H., Huff, S. R. & Boyko, A. L. (2007) Effects of wastewater treatment plant effluent on bat foraging ecology in an urban stream system. *Biological Conservation*, **138**, 120-130.

Kestrel Wildlife Consultants Ltd (2011) *Report on bat surveys carried out in 2011 at Northern United lesser horseshoe bat roost Cinderford, Forest of Dean, Gloucestershire*. Cullompton, Devon.

Homes and Communities Agency (2014) *Environmental Addendum Vol. 2 – Hybrid Planning Application – Northern Quarter Cinderford*. June 2014.

Hope, P. R. & Jones, G. (2013) An entrained circadian cycle of peak activity in a population of hibernating bats. *Journal of Mammalogy,* **94**, 497-505.

Hundt, L. (2012) *Bat Surveys: Good Practice Guidelines*. Bat Conservation Trust, London

Jones, G., Jacobs, D. S., Kunz, T. H., Willig, M. R. & Racey, P. A. (2009) Carpe noctem: the importance of bats as bioindicators. *Endangered Species Research,* **8**, 93-115.

Meddings A., Taylor S., Batty L., Knowles M. & Latham D. (2011) Managing competition between birds and bats for roost boxes in small woodlands, north-east England. *Conservation Evidence*, **8**, 74-80.

Payne, C (2014) *Automated Bat Loggers Wales, UK*. Natural Resources Wales (NRW). Presentation at AuMoBRE 1, 7th Feb 2014. Retrieved from: http://www.zoogdiervereniging.nl/sites/default/files/imce/nieuwesite/0verigen/downloads/Automated%20Bat%20Loggers%20UK%20Cyprian%20Payne.pdf

Russ, J. 1999. *The Bats of Britain and Ireland. Echolocation calls, sound analysis, and species identification*. Powys: Alana Books.

Section 106 agreement (2015) *Details of agreement made between Gloucestershire County Council; Forest of Dean District Council; Homes and Communities Agency*. Bond Dickinson LLP, 26th February 2015.

Wickramasinghe, L. P., Harris, S., Jones, G. & Vaughan, N. (2003) Bat activity and species richness on organic and conventional farms: impact of agricultural intensification. *Journal of Applied Ecology,* **40**, 984-993.

Appendix A: Development plan

Northern Quarter Masterplan Concept, supplied by Forest of Dean District Council.

Appendix B: Mitigation plan

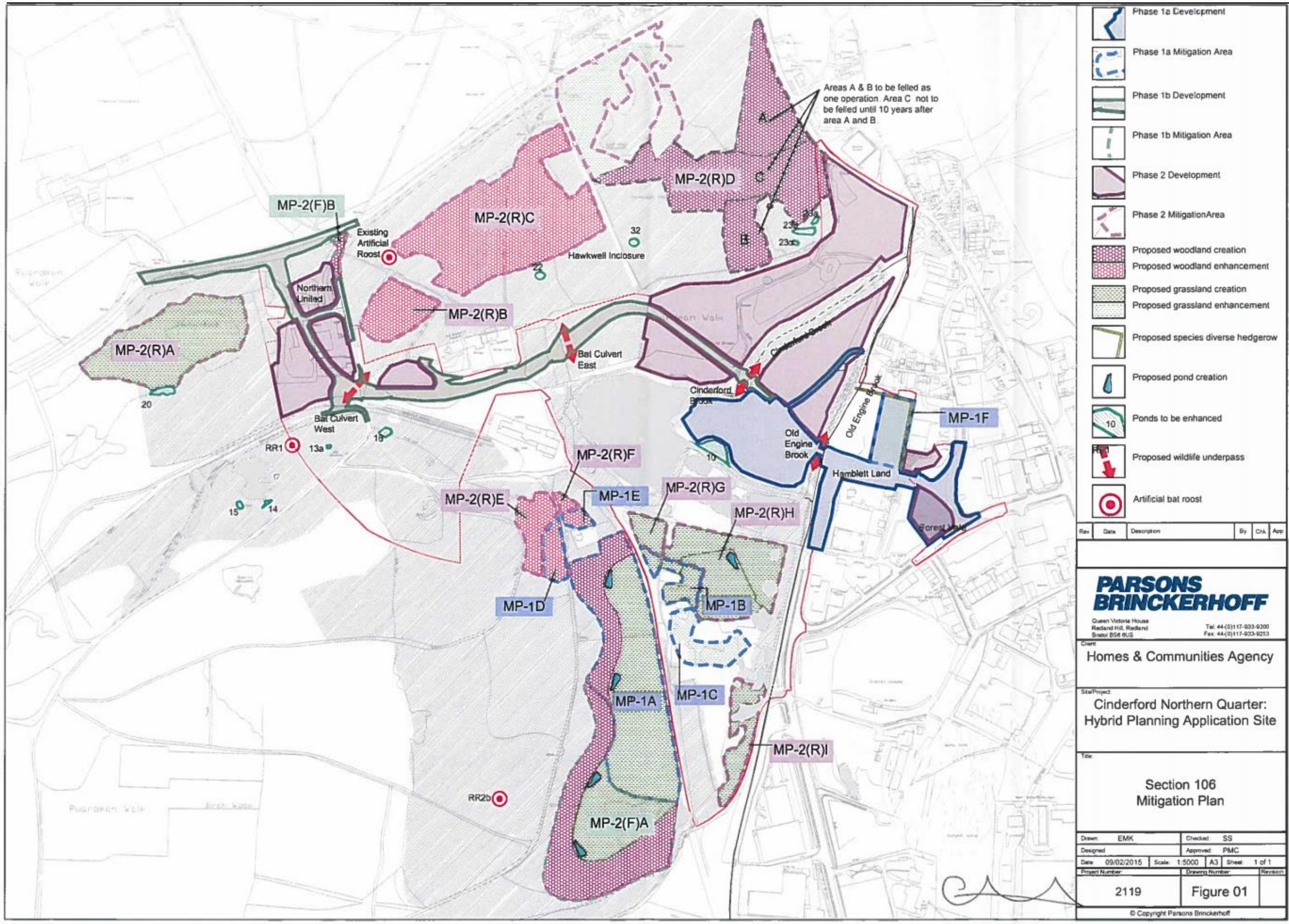


Figure 7.5 from Homes and Communities Agency (2014) *Environmental Addendum Vol. 2 – Hybrid Planning Application – Northern Quarter Cinderford*. June 2014.

Appendix C: Lesser horseshoe bat flightlines

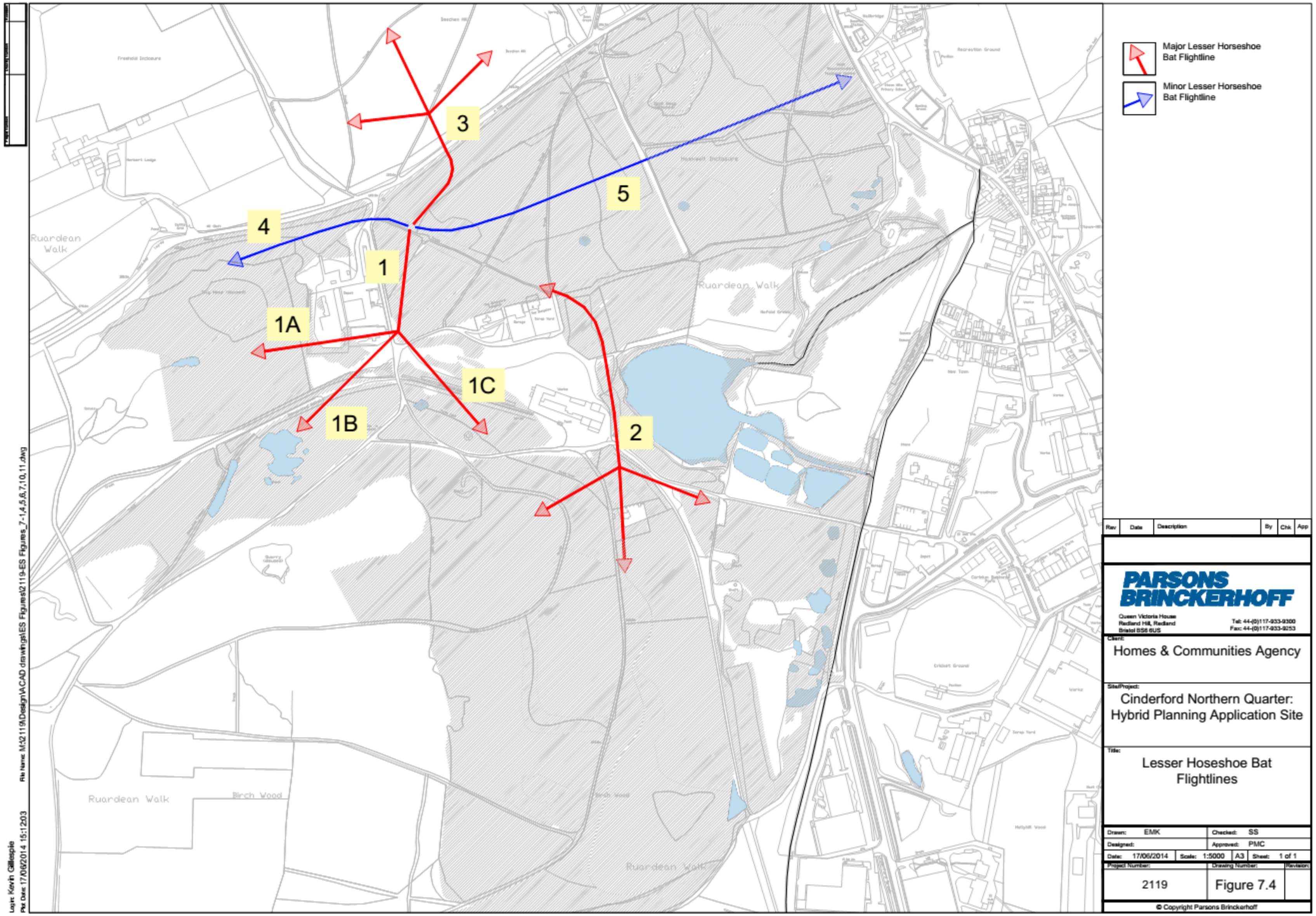


Figure 7.4 from Homes and Communities Agency (2014) *Environmental Addendum Vol. 2 – Hybrid Planning Application – Northern Quarter Cinderford*. June 2014.

Appendix D: Survey datasheet

Date:		Road/structure:			Temp (°C)	Wind (km/h)	Rain (no/light)	Cloud cover (%)
Sunset / sunrise time:		Surveyor position:		Start				
				Middle				
Start time:		Surveyor name:		End				

Record no.	Time on recorder (hh:mm:ss)	Observations of crossing bats				Comments
		Height above ground/road (m)	Distance from feature (m)	Side of feature	Direction crossing	

Survey datasheet additional pages

Record no.	Time on recorder (hh:mm:ss)	Observations of crossing bats				Comments
		Height above ground/road (m)	Distance from feature (m)	Side of feature	Direction crossing	

Appendix E: Experience and qualifications of authors

CURRICULUM VITAE

Anna Berthinussen

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D.O.B: 29 August 1982

PERSONAL PROFILE

I am an experienced bat specialist professionally trained in bat ecology and conservation, and competent in all aspects of bat survey work. I have a strong ecological and scientific research background with a wide range of transferable skills, including project management; experimental design for survey and monitoring; data analysis including statistics and modelling; working with GIS to produce databases, Habitat Suitability Models and maps; writing reports to publication standard in peer-reviewed, international journals; and presenting at conferences and workshops.

ACADEMIC EDUCATION AND QUALIFICATIONS

University of Leeds October 2009 - June 2013	**PhD Degree** Bat Ecology and Conservation Thesis title: *The effect of roads on bats and the effectiveness of current mitigation practice* (funded by University of Leeds Research Scholarship) Supervisor: Professor John Altringham
University of Leeds September 2006 – September 2009	**BSc degree in Zoology** First Class Honours
Easingwold School, North Yorkshire 2000	3 A-levels, grade A (Biology, Geography, General Studies) 1 A-level, grade B (Psychology)

OTHER QUALIFICATIONS

Bat survey or research licence (level 4) *pending*
Holder of a CSCS card (Construction Skills Certification Scheme)
Full driving licence held since 2000

RELEVANT WORK AND RESEARCH EXPERIENCE

Field experience within Professor John Altringham's research group, 2009 – present

- Over six years of field experience using a wide range of survey techniques including echolocation call analysis, bat catching with mist nets and harp traps, handling and visual identification of UK bat species.

Bat Surveyor for Quants Environmental Ltd., Aug 2012 – present

- Sub-contracting work for an ecological consultancy completing nocturnal bat surveys across Yorkshire, including emergence/re-entry surveys and building inspections.

Expert reviewer for BBOWT (Bucks, Berks and Oxon Wildlife Trust), Jan 2014 - present

- Commissioned to review and produce a full report on the High Speed 2 rail Environmental Statement and subsequent amendments (including the approach taken and proposed mitigation) in relation to the potential impact on protected Bechstein's bats in the Bernwood Forest area.
- Report submitted to parliament as part of BBOWT's consultation response.

WC1060 Bats, Roads & Rail project for Defra (Research Fellow, University of Leeds), May 2013 – July 2015

- A postdoctoral position to develop a cost-effective method for monitoring the effect of linear transport infrastructure on bats and the effectiveness of mitigation.
- Involved designing, planning and project managing field work throughout the UK over two years, as well as data analysis, report writing, and liaising with Defra and the project steering group.

Volunteer, Bat Conservation Trust Out of Hours Helpline, May 2015 – September 2015

- Answering emergency calls from the public dealing with issues such as grounded or injured bats, bats trapped in people's houses, newly-discovered roosts and planning and development queries.

Bat Conservation Expert Assessment project (Research Fellow, University of Leeds), March – June 2015

- Coordinated and participated in a project following on from the Bat Conservation Synopsis (2014), whereby the effects of each bat conservation action were evaluated by an international expert panel and categorised according to effectiveness.
- Results published in Conservation Evidence's '*What Works in Conservation?*' Annual Synopsis.

Demonstrator, University of Leeds, 2009 – 2015

- Assisted with teaching of undergraduate and postgraduate courses within the School of Biology, including an MSc Bat Skills course.
- Gave talks to students on bat ecology and survey techniques, and demonstrated the practical skills of working with bats.

Bat Conservation Synopsis project (Research Fellow, University of Leeds), Dec 2012 – April 2013

- A postdoctoral position to produce a Bat Conservation Synopsis.
- Involved consulting an expert panel, searching the global literature and summarising all available evidence for interventions relating to bat conservation in an accessible format.
- Published as a volume of the Synopses of Conservation Evidence series.

PhD research: Summer field work with bats, UK-wide, Jun - Sep 2009, 2010, 2011 & 2012

- Fieldwork experience gained over four seasons investigating the impact of motorways on local bat populations, and the effectiveness of bat gantries and underpasses as mitigation for roads.
- Skills were developed in transect design, acoustic surveying, dusk and dawn observational surveys, echolocation call identification techniques, night vision video recording, and data analysis with software such as BatSound, BatClassify, the R programme, ArcGIS and Maxent.

Bat Surveyor for Total Ecology Ltd., Jun 2012 - Jan 2013

- Sub-contracting work for an ecological consultancy, completing bat surveys at various sites.

Participation in the Nietoperek Annual Winter Bat Census, Poland, Feb 2012

- I was selected to take part in the annual census and gained experience in counting and identifying hibernating European bat species found in the extensive WWII bunker system.

Demonstrator, 'Discovery Zone', Leeds Festival of Science, March/April 2010 & 2011

- Demonstrating science to primary school children (Key Stages 2 and 3).

AWARDS

Vincent Weir Scientific Award – awarded by the Bat Conservation Trust for making a significant contribution to research on the conservation biology of bats, September 2014

First prize for oral presentation - Faculty of Biological Sciences Postgraduate Symposium, University of Leeds, April 2012

University of Leeds Research Scholarship – a highly competitive Scholarship awarded for a three year PhD studentship, 2009 – 2012

'Best overall mark in Zoology programmes' - Year 2 BSc Zoology Prize, University of Leeds, 2007

PUBLICATIONS

Books

Berthinussen, A., Richardson, O. & Altringham J. (2014) *Bat conservation: Global evidence for the effects of interventions*. Exeter: Pelagic Publishing.

Book chapters

Berthinussen, A., Richardson, O.C., Smith, R.K. Altringham, J. D., Sutherland, W.J. (2015) Bat Conservation. In: Sutherland, W.J., Dicks, L.V. & Smith, R.K. (eds) *What Works in Conservation 2015.* Cambridge, UK: Open Book Publishers http://dx.doi.org/10.11647/OBP.0060.

Abbott, I., Berthinussen, A., Boonman, M., Melber, M., Stone, E., Altringham, J. (2015) Bats and roads. In: R. van der Ree, C. Grilo & D. Smith (eds) *Handbook of Road Ecology*. Wiley-Blackwell, p290.

Research papers

Berthinussen, A. & Altringham, J. (2012) Do bat gantries and underpasses help bats cross roads safely? *PLoS ONE* 7, e38775.

Berthinussen, A. & Altringham, J. (2012) The effect of a major road on bat activity and diversity. *Journal of Applied Ecology*, 49, 82-89.

Manuscripts in preparation on:

- The effects of different road classes, road construction and railways on bats
- The effectiveness of road crossing structures for bats: underpasses, wire bat bridges and a green bridge

Reports to government agencies etc.

Berthinussen, A. & Altringham J. (2015) *WC1060: Development of a cost-effective method for monitoring the effectiveness of mitigation for bats crossing linear transport infrastructure.* Final report to Defra.

Berthinussen, A. & Altringham J. (2015) *Appraisal of HS2 Ltd Supplementary Environmental Statement and Additional Provision 2 in relation to the bat community in the Bernwood Forest area, with particular reference to Bechstein's bat*. Report for Berks, Bucks, Oxon Wildlife Trust (BBOWT).

Berthinussen, A. & Altringham J. (2014) *Appraisal of HS2 Ltd Environmental Statement in relation to the bat community in the Bernwood Forest area, with particular reference to the Bechstein's bat*. Report for Berks, Bucks, Oxon Wildlife Trust (BBOWT).

CONFERENCE PRESENTATIONS

'*Bats, roads and mitigation'* Oral presentation at CIEEM (Chartered Institute of Ecology and Environmental Management) West Midlands Annual General Meeting, Nyquist Theatre, Solihull, October 2015

'*Bats, roads and evidence-based conservation'* Oral presentation, National Bat Conference 2014, Bat Conservation Trust, Warwick, September 2014

'*The effect of a major road on bat activity and diversity, and the effectiveness of current mitigation practice'*
Oral presentation, IENE (Infra Eco Network Europe) International Conference September, Malmö, Sweden 2014

'Roads, railways and bats – impacts, mitigation and future practice'
Oral presentation at CIEEM (Chartered Institute of Ecology and Environmental Management) workshop, University of Leeds, February 2014

'*The effect of a major road on bat activity and diversity, and the effectiveness of current mitigation practice'*
Oral presentation, 3rd International Berlin Bat Meeting, March 2013

'The effect of a motorway on bat activity in the UK'
Oral Presentation, Faculty of Biological Sciences Postgraduate Symposium, University of Leeds, April 2012
Awarded 1st prize

'Bats, roads and mitigation'
Poster presentation, BritBats conference, Zoological Society London, April 2010

CURRICULUM VITAE

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EDUCATION AND ACADEMIC CAREER

1975-1978	University of York, Dept. of Biology. BA (Hons) Biology
1978-1981	University of St. Andrews, Dept. of Physiology. PhD
1981-1983	University of Washington, Seattle, WA. USA. SERC/NATO Personal Fellowship
1983-1989	University of St. Andrews, Dept. Biology. NERC, SERC (2) Postdoctoral Fellowships
1989-1992	University of Leeds, Lecturer in the Department of Pure and Applied Biology
1993-1996	Senior Lecturer
1996-1999	Reader in Comparative Physiology
1999- 2010	Professor of Biomechanics
2010- present	Professor of Animal Ecology & Conservation

MAJOR PERSONAL AWARDS

Awarded the Scientific Medal of the Zoological Society of London in 1994 “for distinguished work in zoology”

CURRENT INTERESTS: RESEARCH & CONSERVATION

A long term interest in bats has developed into a primary research area: behaviour, ecology and conservation of bats, the most diverse mammalian order. Because flight and echolocation are central to the behaviour and ecology of bats, my background in biomechanics and physiology is of considerable value.

I am interested in how the behaviour of individual animals is related to their ecology and environment and how these interact to determine small and large scale population structure. I use a wide range of field techniques, in combination with molecular genetics to investigate foraging behaviour, social and mating systems and migration.

Conservation is a major driver of much of my work, from the conservation of bats themselves to broader topics, e.g. bats as ecosystem service providers in the tropics and as biodiversity indicators. Current work is centred around the effects of roads and rail on bats, survey methods for woodland bats, and the development and application of GIS-based habitat suitability modelling. The modelling improves ecological understanding of habitat use by bats and birds, and the models generate maps that are being used as conservation planning tools by national parks and other bodies.

Long association with the Yorkshire Dales National Park led me to form the Yorkshire Dales Environment Network in 2012, with NERC funding, to promote more effective communication and collaboration between the many organisations that help conserve the Dales.

EXTERNAL APPOINTMENTS ETC.

Since much of my current work has applications in conservation I have become increasingly involved with conservation organisations. I sit on a number of advisory panels and use the opportunities presented to promote evidence-based approaches in conservation.

Current posts/activities

Natural England (NE) trainer for the catching, handling and study of protected bat species. I run training courses and undertake technical reviews for NE and other government agencies and NGOs.

Member of Yorkshire Dales National Park Biodiversity Forum advising on conservation policy and strategy
Member of NE/Bat Conservation Trust National Biodiversity Action Plan Panel for bats
Member of the National Trust's Natural Environment Panel, giving broad science and conservation advice nationally to the UK's largest landholder for conservation
I serve regularly as an expert witness to public inquiries on conservation/development issues
I advise a range of organisations on conservation issues. I am currently advising the Wildlife Trusts on the likely impact of the proposed high speed rail-link HS2.

Past posts

Advisor to Welsh Agri-environment Monitoring Scheme: Countryside Council for Wales (CCW) and Bat Conservation Trust (BCT)
BBSRC Animal Sciences grants committee
Council member of Bat Conservation Trust
Scholarship Program panel of Bat Conservation International, USA
Various NE/BCT committees/panels related to bat conservation

PUBLIC ENGAGEMENT IN SCIENCE

I am a regular **advisor** to the BBC Natural History Unit for a wide range of TV programmes, including *The Natural World*, *Life of Mammals*, *Planet Earth* and *Springwatch/Autumnwatch*.

I **contribute** regularly to BBC Natural History Unit programmes through appearances and occasional **writing and presenting**, e.g. in the Radio Four series *Nature* and *Saving Species* and on BBC TV *Autumnwatch,* as well as many one-off programmes such as the recent *The Great British Countryside* (BBC1) and *The Listeners* (R4).

I also contribute to and advise ITV, Channel 4 and independent productions

In addition to giving research seminars and national/international conference presentations I am regularly invited to speak to government and other conservation organisations such as NE, NRW, BCT, CIEEM. I have also run 1 and 2 day training courses for conservation professionals in survey and research techniques and evidence-based conservation.

I give numerous invited public talks, primarily on bats, but also other biological subjects.

RESEARCH GROUP

Recent research funding sources

Natural Environment Research Council
Dept. for the Environment, Food and Rural Affairs
Countryside Council for Wales (now Natural Resources Wales)
Forestry Commission
Food and Environment Research Agency
Leverhulme Trust
Natural England
North York Moors National Park Authority
People's Trust for Endangered Species
Yorkshire Dales National Park Authority
Northumberland National Park Authority

PUBLICATIONS

I have published over 150 scientific papers and reports, numerous book chapters and three books.

Selected publications from 2010:

Books

Altringham JD. (2011) **Bats: from evolution to conservation.** Oxford University Press. 324 pages.

Berthinussen A, Richardson OC and Altringham JD (2013) **Bat conservation: global evidence for the effects of interventions**. Synopses of conservation evidence series. Pelagic Publishing. 110 pages. http://www.conservationevidence.com/synopsis/index

Book chapters

Abbott I, Berthinussen A, Stone E, Boonman M, Melber M and Altringham J. (2015) Bats and roads. Chapter 34 in Handbook of Road Ecology. van der Ree, R., Smith, D.J. and Grilo, C (eds.). John Wiley & Sons, Oxford. 552 pp. ISBN: 978-1-118-56818-7.

Altringham JD, and Kerth G (2015) Bats and roads. In: Bats in the Anthropocene: conservation of bats in a changing world. Edited by CC Voigt and T Kingston. Springer, Berlin. In press.

Berthinussen A and Altringham JD (2015) Bats. In: What Works in Conservation. Compiled by William J. Sutherland, Lynn V. Dicks, Nancy Ockendon and Rebecca K. Smith. Pelagic Publishing and Conservation Evidence.

Research papers

Jan C, Frith, K, Glover AM, Butlin RK, Scott CD, Greenaway F, Ruedi M, Franz AC, Dawson DA and Altringham JD. (2010) *Myotis alcathoe* confirmed in the UK from mitochondrial and microsatellite DNA. **Acta Chiropterologica** 12, 471-483.

Bradter U, Thom TJ, Altringham JD, Kunin WE, Benton TG. (2011) Prediction of National Vegetation Classification (NVC) communities in the British uplands using environmental data at multiple spatial scales, aerial images and the classifier random forest. **Journal of Applied Ecology** 48, 1057-1065.

Jan C, Dawson DA, Altringham JD, Burke TA, Butlin RK. (2012) Development of conserved microsatellite markers of high cross-species utility in bat species (Vespertilionidae, Chiroptera, Mammalia). **Molecular Ecology Resources** 12, 532-548.

Berthinussen A and Altringham JD. (2012) The effects of a major road on bat activity and diversity. **Journal of Applied Ecology**. 49, 82-89.

Berthinussen A and Altringham JD. (2012) Do bat gantries and underpasses help bats cross roads safely. **PLoS ONE** 7(6): e38775.

Rigby EL, Aegerter J, Brash M and Altringham JD (2012) Impact of PIT tagging on recapture rates, body condition and reproductive success of wild Daubenton's bats (*Myotis daubentonii*). **Veterinary Record** doi: 10.1136/vr.100075

Angell RL, Butlin RK and Altringham JD. (2013) Sexual segregation and flexible mating patterns in temperate bats. **PLoS ONE** 8(1): e54194.

Bellamy CC, Scott CD and Altringham JD. (2013) Multiscale, presence-only habitat suitability models: fine resolution models for eight bat species. **Journal of Applied Ecology.** 50, 892-901.

Bradter U, Kunin WE, Altringham JD, Thom TJ, Benton TG. (2013) Identifying appropriate spatial scales of predictors in species distribution models with the random forest algorithm. **Methods in Ecology and Evolution** 4, 167-174.

Fletcher T, Altringham J, Peakall J, Wignall, P and Dorrell R (2014) Hydrodynamics of fossil fishes. **Proceedings of the Royal Society B** 281, 20140703.

Gardiner JD, Altringham JD, Papadatou P and Nudds RL (2014) Excepting *Myotis capaccini*, the wings' contribution to take-off performance does not correlate with foraging ecology in six species of insectivorous bat. **Biology Open** doi:10.1242/bio.20149159.

Wordley CFR, Foui EK, Mudappa D, Sankaran M and Altringham JD (2014) Acoustic identification of bats in southern Western Ghats, India. **Acta Chiropterologica** 16, 213-222.

Bellamy CC and Altringham JD. (2015) Predicting species distributions using record centre data: multi-scale modelling of habitat suitability for bat roosts. **PLoS ONE**. e0128440.

Wordley CFR, Sankaran M, Mudappa D and Altringham JD (2015) Habitat preferences of bats in the Western Ghats of India: bats like something in their tea. **Biological Conservation**. In press.

Selected reports for government agencies, etc.

Bellamy CC and Altringham JD. (2012) Bat Habitat suitability modelling and maps for the Lake District National Park. For the **LDNPA & Natural England (Cumbria)**.

Bellamy CC and Altringham JD. (2012/3) Bat Habitat suitability modelling and maps for the North York Moor Moors National Park. For the **NYMNPA**. Two parts.

Bellamy CC and Altringham JD. (2012/13) Bat Habitat suitability modelling and maps for the Yorkshire Dales National Park. For the **YDNPA**. Two parts.

Glover AM and Altringham JD. (2013) The use of methods and devices for catching and marking bats to support Natural England's Bat Class Survey and project licensees. For **Natural England**.

Altringham JD (2013) Effects of HS2 on biodiversity: commentary on the Phase Two Consultation. Report for the **National Trust**.

Berthinussen A and Altringham JD (2014) Appraisal of HS2 Ltd Environmental Statement in relation to the bat community in the Bernwood Forest area, with particular reference to Bechstein's bat. Report for the **Berks, Bucks and Oxon Wildlife Trust**.

Scott S and Altringham JD (2014) Developing effective methods for the systematic surveillance of bats in woodland habitats in the UK. Research Contract WC1015, **Defra**.

Berthinussen A and Altringham JD (2015) Development of a cost-effective method for monitoring the effectiveness of mitigation for bats crossing linear transport infrastructure. Research Contract WC1060, **Defra**. Publication delayed due to general election purdah.

I make regular contributions to zoological and conservation journals, magazines and newsletters at home and abroad.